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ENVIRONMENTAL EFFECTS OF DREDGING TECHNICAL NOTES
(EEDTN)(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION
VICKSBURG MS JUN 85

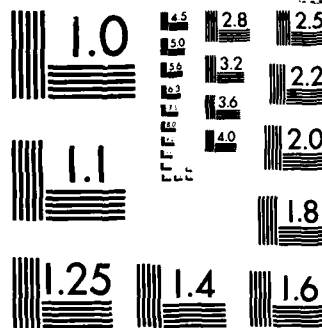
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DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P.O. BOX 631
VICKSBURG, MISSISSIPPI 39180

REPLY TO
ATTENTION OF

WESEP-D

SUBJECT: Environmental Effects of Dredging Technical Notes (EEDTN)

1. This is the first EEDTN mailing from the Waterways Experiment Station. The one- to six-page notes on environmental effects of dredging are based on ongoing or recently completed research and/or unique Corps field projects and will identify problem areas and give techniques or approaches for solution. The technical notes will be issued in a form for insertion in the enclosed loose-leaf notebook to facilitate the addition of new material and revisions of previously issued pages.
2. The following areas are indexed and tabbed in the notebook:
 - a. EEDP-01 Aquatic Disposal
 - b. EEDP-02 Upland Disposal
 - c. EEDP-03 Wetland/Estuarine Disposal
 - d. EEDP-04 Regulatory
 - e. EEDP-05 Design/ConOps
 - f. EEDP-06 Management
 - g. EEDP-07 Beneficial Uses
 - h. EEDP-08 Miscellaneous
 - i. EEDP-09 Equipment
3. The state-of-the-science procedures and the state-of-the-practice field demonstrations described in the technical notes will have primary distribution to the field offices of the Corps of Engineers. The EEDTN will be issued to specific individuals in Corps offices.
4. For information on the technical notes including additions to the distribution list, contact Dr. Robert M. Engler, Manager, Environmental Effects of Dredging Programs, at (601)634-3624 or FTS 542-3624.

FOR THE COMMANDER AND DIRECTOR:

Encl

JOHN W. KEELEY
Acting Technical Director

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Environmental Effects of Dredging Technical Notes

EEDP-01-1
June 1985



Dist

A-1

BIOMAGNIFICATION OF CONTAMINANTS IN AQUATIC FOOD WEBS AS A RESULT OF OPEN-WATER DISPOSAL OF DREDGED MATERIAL

PURPOSE: This note provides information regarding the potential extent of biomagnification (the tendency for contaminant concentrations in animal tissues to increase through successively higher trophic levels) of contaminants in aquatic food chains resulting from the open-water disposal of contaminated dredged material. The note also provides a technically sound perspective and offers general technical guidance on assessing the environmental importance of biomagnification in aquatic food chains as a result of open-water disposal of contaminated dredged material. It does not consider biomagnification in nonaquatic organisms.

BACKGROUND: Disposal of dredged material in open water is used extensively by the Corps of Engineers. Pesticides and pesticide residues, nutrients, organic wastes, heavy metals, and other contaminants entering waterways may associate strongly with particulate materials and eventually accumulate in the sediments. The presence of potentially toxic contaminants in some sediments has generated concern that dredging and open-water disposal of contaminated dredged material may cause the deterioration of the aquatic environment. It is felt that persistent chemical residues from the dredged material may accumulate within the tissues of aquatic plants and animals to levels that are in excess of the ambient concentrations in their environment. Most of these substances have no known biological function, and there is concern that some may accumulate to levels that could affect the growth, reproduction, or survival of the organism or its predators.

Although well documented in terrestrial ecosystems, the occurrence and extent of biomagnification in aquatic ecosystems is questionable and is the topic of considerable debate. In 1983, extensive independent literature reviews were prepared by the Corps of Engineers (Kay 1984) and the Environmental Protection Agency (Biddinger and Gloss 1984) to assess the magnitude of contaminant biomagnification in aquatic ecosystems. The Corps literature review was conducted as part of the Long-Term Effects of Dredging Operations (LEDO) Program.

There were some minor differences between the two reviews, but both reached very similar conclusions regarding biomagnification of contaminants in aquatic food webs. The findings of these literature reviews provide the basis of this Technical Note on biomagnification as a potential contaminant mobility problem originating from the open-water disposal of contaminated dredged

material. The ecological consequences of any presumed biomagnification of contaminants are beyond the scope of this note. See Dillon (1984) for information regarding the consequences of contaminant accumulation in aquatic animals.

ADDITIONAL INFORMATION: Contact the author, Dr. Stratford H. Kay, (601) 634-2387 (FTS 542-2387), or the acting EEDP Program Manager, Dr. Robert M. Engler, (601) 634-3624 (FTS 542-3624).

The Phenomenon of Biomagnification

Many chemicals are present in the environment in extremely low concentrations, frequently near or below the levels readily detectable by routine analytical techniques. Living organisms may accumulate these chemicals to levels greatly in excess of the ambient concentrations in their environment. The ability to accumulate substances from the environment is biologically significant, for this is how living organisms obtain these substances commonly designated as "essential nutrients." However, nonessential chemicals (e.g. trace substances) also may be accumulated from the environment by natural biological processes. These substances have no known biological function and can accumulate to levels that may be detrimental to the organism.

Trace substances may enter living organisms in several ways. Both aquatic plants and animals accumulate trace substances by bioconcentration (direct adsorption and absorption from the sediments and water). Animals also accumulate trace substances by ingestion. The total process of accumulating substances by both ingestion and bioconcentration is called bioaccumulation. Occasionally, the concentrations of trace substances in living organisms continue to increase as the substances are passed on from lower to higher trophic levels. This phenomenon is called biomagnification.

The relative importance of food and bioconcentration as pathways for entrance of trace contaminants into aquatic organisms is the subject of considerable debate. The predominant route of entrance of a contaminant into a living organism depends on the nature of the environment itself and the relative level of exposure in the food and the external environment. Food becomes the primary source for contaminant accumulation only when bioconcentration from the external environment is minimal. Food-chain biomagnification as the result of dietary intake of contaminants is said to occur if the concentration of a substance increases at each successively higher trophic level as the result of dietary intake of food (prey) by a consumer (predator).

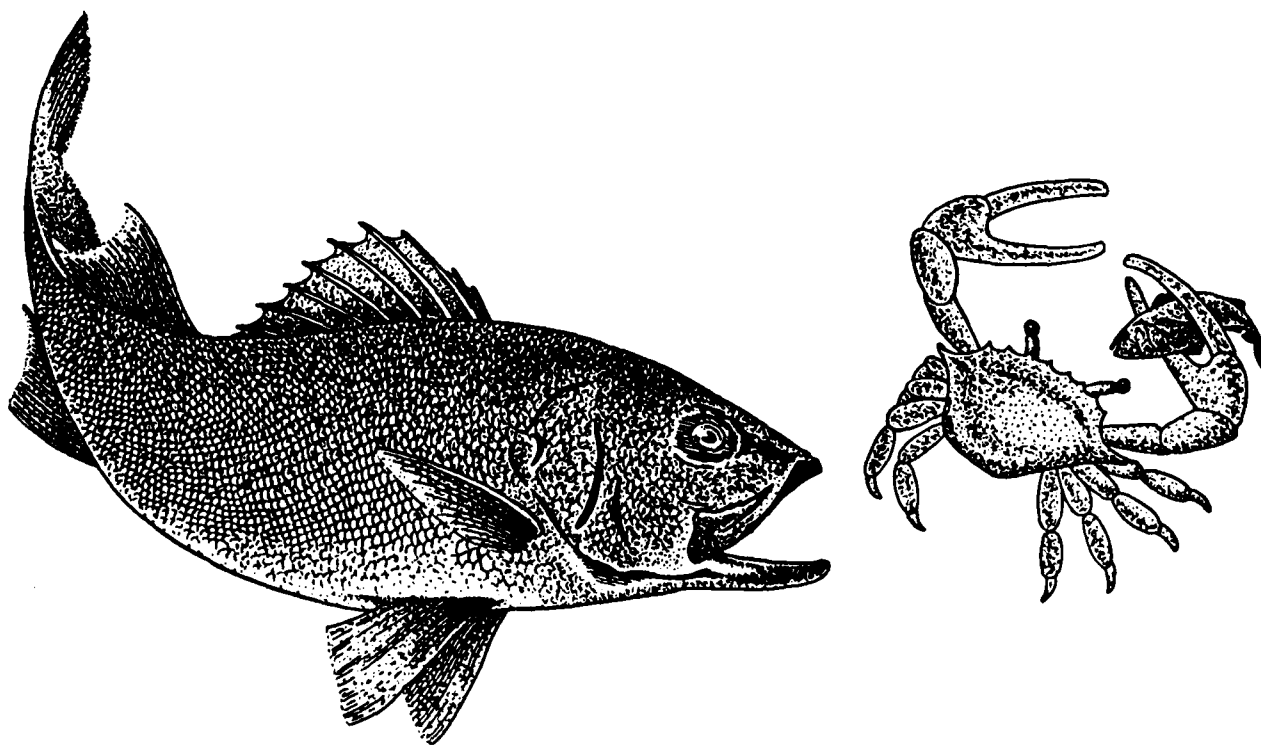
Biomagnification of contaminants may occur when all of the following conditions are met:

The chemical is persistent in biological systems (Macek 1970).

Direct uptake from the external medium is minimal.

The food pathway is essentially linear and highly structured, and the predominant energy flow is from lower to higher trophic levels.

Most aquatic (freshwater and marine) food webs are rather weakly structured, however, and do not have trophic levels as clearly defined as those of terrestrial systems. One species may occupy several trophic levels during its lifetime due to different feeding habits at different stages in its life cycle. Opportunistic omnivores also feed upon organisms occupying several trophic levels. Energy flow in aquatic food webs is multidirectional (for example, crabs are both prey and scavengers of fish), and a large component of the energy in aquatic systems is bound within the detritus.



Aquatic systems also rarely meet the criterion of minimal uptake from the external medium. Contaminant levels in the water may be low, but are usually higher than levels found in the atmosphere. In comparison to terrestrial animals (terrestrial is extended to include all animals that breathe air via lungs; shorebirds and "aquatic" mammals are considered as a special case of

terrestrial animals living partially or wholly in water and are not covered herein), aquatic (water-breathing) animals have large respiratory areas in proportion to body size. The solubility of oxygen in water, especially seawater, is low. Therefore, ambient oxygen available for respiration is substantially less for most water-breathing aquatic animals than for their air-breathing counterparts. Large quantities of water must be passed over their gill surfaces to provide adequate oxygen for respiration, simultaneously increasing the uptake of other essential and nonessential substances from the surrounding medium. The body integuments (coverings) of aquatic animals, especially invertebrates, are usually more permeable than the integuments of terrestrial animals, allowing chemicals to pass readily into and from their tissues.

The combination of intimate physical contact with the external medium, due to relatively permeable body surfaces and respiration via gills, and a complexly interactive trophic web has led to the conclusion that trace contaminants probably do not increase nearly as much with trophic levels (i.e., biomagnify) in aquatic systems as in nonaquatic systems (Isaacs 1975). Thus diet generally is thought to be of minor importance as a source of most contaminants in the aquatic food web (Scura and Theilacker 1977; Macek, Petrocelli, and Sleight 1979; Narbonne 1979).

Summary of Findings of the Literature Reviews

Heavy metals

The majority of the data reviewed by Kay (1984) and Biddinger and Gloss (1984) indicated that most heavy metals except methylmercury do not biomagnify either in freshwater or marine food webs. A review of field and laboratory studies (Kay 1984) showed that food may be an important source for the bioaccumulation of toxic heavy metals, particularly those that are essential trace elements (copper, zinc, and selenium), but also some that have no known metabolic functions (chromium, arsenic, cadmium, mercury, and lead). These elements may be taken up from food, but do not biomagnify to any extent from one trophic level to the next within the food web. Concentrations of these elements generally were higher in the tissues of benthic herbivores and detritivores and, occasionally, planktivores than in the top-level carnivores.

In the case of methylmercury, laboratory evidence reviewed by Kay (1984) suggested that biomagnification would not occur, but was contradicted

by the majority of the field studies, which indicated biomagnification. Both the Corps and the EPA reviews found that methylmercury has an affinity for muscle and tissues and apparently is biomagnified through the trophic web to the top predators. Consequently, higher, although not necessarily harmful, concentrations of methylmercury frequently are found in the large commercially valuable fishes than in invertebrates. However, the magnitude of increase from low trophic levels to high is on the order of one to ten times, not tens or hundreds of thousands of times as may occur in nonaquatic food webs. There is no satisfactory explanation for the contradictory results of laboratory and field studies with respect to methylmercury biomagnification.

Kay (1984) noted that inorganic mercury does not appear to biomagnify in aquatic food webs. Biddinger and Gloss (1984) also indicated that selenium and zinc might biomagnify; Kay (1984) noted that food was an important source for both metals, but did not indicate biomagnification.

Organic compounds

Food chain studies indicate that diet may contribute to the body burdens of a number of chlorinated and nonchlorinated organic compounds present in aquatic animals. Kay (1984) concluded that those compounds which appear to have potential for biomagnification in aquatic food webs were the polychlorinated biphenyls (PCB), kepone and mirex, benzo[a]pyrene, and naphthalenes. Biddinger and Gloss (1984) agreed on PCBs and added DDT to the biomagnification list. Kay (1984) found no strong evidence for biomagnification of DDT in water-breathing animals. However, where biomagnification occurred, it produced concentrations on the order of one to ten times higher in the upper trophic levels than in the lower ones, in contrast to the tens or hundreds of thousands of times higher as has occurred in such nonaquatic food webs as those involving DDT in fish-eating birds (Kay 1984).

As in the case of the heavy metals, the data on these organic contaminants sometimes were contradictory. Although top predatory fishes often contained higher levels of specific contaminants than other members of the food web, the relationship between contaminant levels in the tissues and an organism's position in the food web was not clear. The apparent contradictory nature of the data may reflect a number of factors, including the mobility of the top predators, age and size differences, inadequate understanding of the feeding habits of different species, particularly with respect to the changing of feeding habits at different stages of the life cycle, imprecision in the

assignment of trophic levels, and inadequate sampling and analytical procedures.

The most obvious finding of both reviews was that few organic compounds appear to biomagnify; however, relatively little information was available regarding the behavior of many of the compounds in aquatic food webs. Consequently, any absolute statement regarding the occurrence of biomagnification of these contaminants must be reserved until further data are available.

Conclusions and Implications

The literature reviews were prepared independently, almost simultaneously, and covered a similar range of heavy metals and organic compounds, and reached similar conclusions. The information from the reviews was consistent with the findings of other investigators (Inaacs 1975; Scura and Theilacker 1977; Macek, Petrocelli, and Sleight 1979; Narbonne 1979).

The available information indicates that biomagnification of contaminants is not a dramatic phenomenon in marine and freshwater food webs. Without doubt, most heavy metals and organic compounds do not biomagnify substantially over several trophic levels in obligate aquatic food webs. Kay (1984) and Biddinger and Gloss (1984) agreed that those few contaminants that may have the potential to biomagnify definitely included methylmercury and PCBs; and that selenium, zinc, benzo[a]pyrene, DDT, naphthalenes, kepone, and mirex may possibly biomagnify. The apparent biomagnification of these contaminants in aquatic food webs usually is by small factors (1, 2, 3, 3, etc.) rather than by orders of magnitude (10, 100, 1000, etc.) from the lowest to highest trophic levels.

It is considered unlikely that dredging of contaminated sediment and immediate placement in an open-water disposal area would cause any significant long-term changes in the chemical characteristics of the sediments or substantially alter the bioavailability of the contaminants in the sediment. Contaminant uptake from sediments and mobility within the aquatic food chain should be similar regardless of whether those sediments were left undisturbed or were dredged and placed in an open-water disposal site. Therefore, based on existing literature, it appears unlikely that the open-water disposal of contaminated dredged material will cause any widespread ecological perturbations due to contaminant biomagnification in aquatic food webs. Further concern and expenditure for research on contaminant biomagnification originating

from open-water disposal of contaminated dredged material appears to be unjustified.

Further attention should be given to evaluating biomagnification in food webs that include both aquatic and nonaquatic components, which was beyond the scope of these reviews. When food webs have major components in both aquatic and nonaquatic environments, such as the case of birds feeding on fish, biomagnification by large factors is possible and deserves serious consideration and evaluation. Placement of contaminated dredged material in a wetland or upland environment could impact associated nonaquatic portions of food webs.

Literature Cited

Biddinger, G. R., and Gloss, S. P. 1984. "The Importance of Trophic Transfer in the Bioaccumulation of Chemical Contaminants in Aquatic Ecosystems," *Residue Reviews*, 91:103-145.

Dillon, T. M. 1984. "Biological Consequences of Bioaccumulation in Aquatic Animals," Technical Report D-84-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Isaacs, J. D. 1975. "Assessment of Man's Impact on Marine Biological Resources," Marine Pollution and Marine Waste Disposal, E. A. Pearson and E. de F. Frangipane, Editors, Pergamon Press, Elmsford, New York, pp. 329-340.

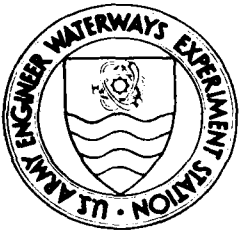
Kay, S. H. 1984. "Potential for Biomagnification of Contaminants within Marine and Freshwater Food Webs," Technical Report D-84-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Macek, K. J. 1970. "Biological Magnification of Pesticide Residues in Food Chains," The Biological Impact of Pesticides in the Environment, J. W. Gillett, Editor, Environmental Health Sciences Series No. 1, Oregon State University, Corvallis, Oregon, pp. 17-21.

Macek, K. J., Petrocelli, S. R., and Sleight, B. H., III. 1979. "Considerations in Assessing the Potential for, and Significance of, Biomagnification of Chemical Residues in Aquatic Food Chains," Aquatic Toxicology, L. L. Marking and R. A. Kimerle, Editors, ASTM STP 667, American Society for Testing and Materials, Philadelphia, pp. 251-268.

Narbonne, J. F. 1979. "Accumulation of Polychlorinated Biphenyl (Phenoclor DP6) by Estuarine Fish," Bulletin of Environmental Contamination and Toxicology 22:60-64.

Scura, E. D., and Theilacker, G. H. 1977. "Transfer of the Chlorinated Hydrocarbon PCB in a Laboratory Marine Food Chain," Marine Biology, 40:317-325.



EEDP-02-1
June 1985



Environmental Effects of Dredging Technical Notes

PLANT BIOASSAY OF DREDGED MATERIAL

PURPOSE: This note introduces the concept of using a plant as an indicator of the contaminants in dredged material. An example of the application of a plant bioassay procedure to saltwater dredged material placed in an upland disposal site was reported in a paper entitled "Contaminant Uptake by *Spartina alterniflora* from an Upland Material Disposal Site -- Application of a Saltwater Plant Bioassay," which was presented at the International Conference on Heavy Metals in the Environment in Heidelberg, Germany, and was published in the proceedings of the conference (Folsom and Lee 1983). The text of this note was taken from the paper.

BACKGROUND: Plant bioassay test procedures are being developed under the Long-Term Effects of Dredging Operations Program and are being field tested and verified under the "Interagency Field Verification of Testing and Predictive Methodologies for Dredged Material Disposal Alternatives," called the Field Verification Program (FVP). These procedures are relatively simple and can provide information that may be required in the ecological evaluation and environmental assessment of dredged material disposal. Based on laboratory results and limited field testing, the procedures can be applied to saltwater sediment or dredged material that requires placement in a wetland or upland environment. The concept presented in this note is the result of ongoing research under the FVP.

ADDITIONAL INFORMATION: Contact one of the authors, Dr. Bobby L. Folsom, Jr. (601) 634-3720 (FTS 542-3720) or Dr. Charles R. Lee (601) 634-3585 (FTS 542-3585), or the EEDP Program Manager, Dr. Robert M. Engler (601) 634-3624 (FTS 542-3624).

Introduction

Recently, a solid-phase plant bioassay was developed to test sediment for contaminants that are potentially phytotoxic and may be bioaccumulated by plants (Folsom and Lee 1981a; Folsom, Lee, and Bates 1981). The solid phase plant bioassay was shown to be an excellent tool for predicting whether or not

contaminants (e.g., zinc and cadmium) were potentially bioaccumulated by the saltwater plant *S. alterniflora*. Folsom and Lee (1981a) pointed out, however, that the DTPA extraction data indicated that plant uptake from air-dried oxidized saltwater sediment would be substantially greater than from the same saltwater sediment under flooded reduced conditions. In addition, they suspected greater plant uptake once the excess salts were leached out and the sediments were dried. This technical note reports results of modifications to the original solid-phase plant bioassay to pursue this assumption.

Methodology

A sediment from Black Rock Harbor (BRH) in Bridgeport, Connecticut, was selected for this study due to its extremely high concentrations of one or more contaminants. The sediment was analyzed for texture, salinity, organic matter, conductivity, calcium carbonate equivalent, pH, total sulfur, oil and grease, and heavy metals (total nitric acid digestible and DTPA extractable).

The solid-phase plant bioassay was conducted in an experimental unit similar to the one shown in Figure 1, which was used in earlier studies (Folsom and Lee 1981a). Procedures for the flooded condition were essentially the same as those used previously. The upland condition was prepared by washing one volume (1 l) of original flooded sediment with three volumes (3 l) of reverse osmosis (RO) purified water. An electric stirrer was used to mix the sediment and water; the solids in the resulting suspension were allowed to settle out (about 4 days); and the supernatant was siphoned off. The sediment was washed two more times using the same procedure, and then the washed sediment was air-dried.

The washed air-dried (upland) sediment to be tested was placed into the inner container of the solid-phase bioassay apparatus. Water of appropriate salinity (15 parts per thousand) was added to the flooded sediment. RO water was added to the air-dried sediment initially to moisten the sediment and to promote seedling growth. Additional water was added only to meet the needs for plant growth. From this point on, the procedure of Folsom and Lee (1981a) was followed with the exception that only *S. alterniflora* was grown as the index plant.

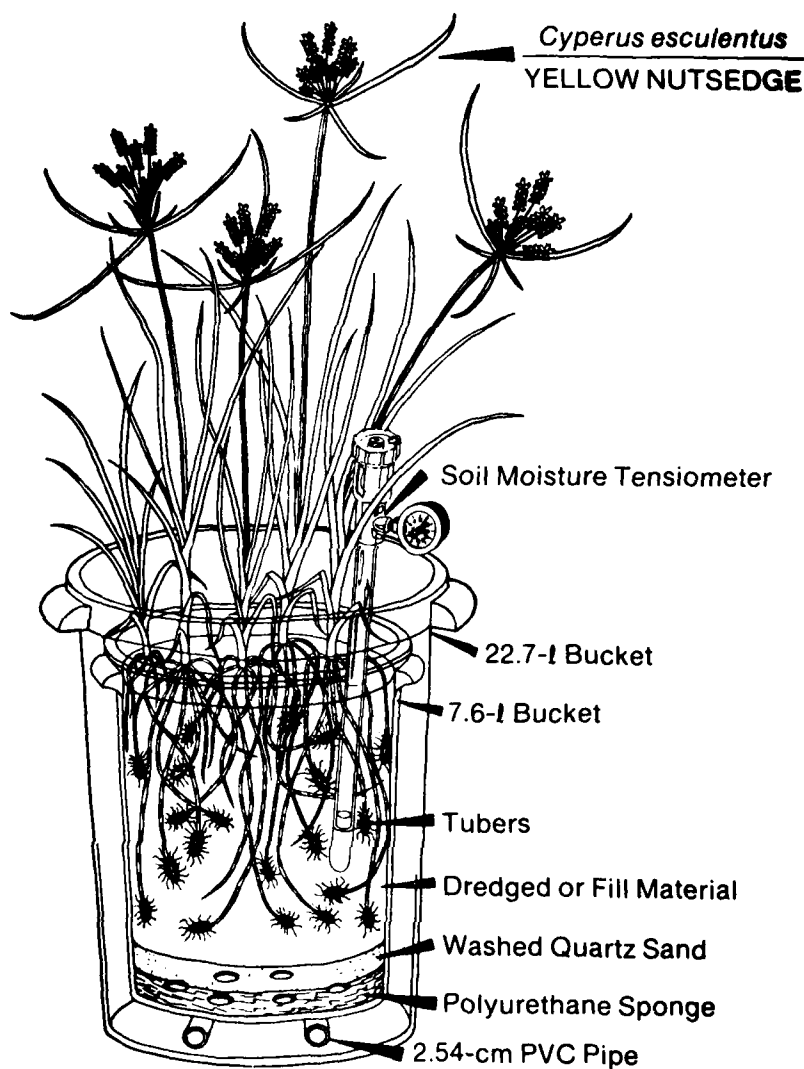


Figure 1. Schematic diagram of the experimental unit used for solid-phase plant bioassays

Results and Discussion

Selected physical and chemical parameters of the BRH sediment were determined to be as follows:

Organic matter, %	18.7
Salinity, ppt	25.3
Conductivity, dS/m	35.7
CaCO ₃ equivalent, %	1.0
pH: wet	7.6
reconstituted air-dried	6.6
Oil and grease, mg/g	5.3
Total Sulfur, %	1.3

The total amounts and DTPA-extractable heavy metal concentrations in BRH sediment are shown in the following tabulation:

Heavy Metal	Concentration, $\mu\text{g/g}$			
	Total Acid Digestible- Original Sediment	DTPA Extractable		
		Original Sediment Flooded	Upland	Washed Sediment, Upland
Zinc	1264	1.73	765	1017
Cadmium	16.7	<0.0005	22.0	24.7
Copper	2377	<0.005	701	235
Chromium	1346	0.18	1.45	1.62
Lead	330	0.01	14.3	23.2

The total sediment content of heavy metals was typical for that of contaminated saltwater sediment with the exception of copper, which was much greater (Folsom, Lee, and Bates 1981).

The data for the DTPA-extractable heavy metals in the BRH sediment showed that air-drying resulted in increased heavy metals extractability. Washing the sediment before air-drying had only a slightly increased effect on DTPA extractability of the heavy metals. The DTPA data would predict plant uptake of heavy metals to be greater from the air-dried upland sediment compared to the original flooded sediment.

Contents of the heavy metals in the leaf tissues of *S. alterniflora* grown in original sediment under both flooded and upland conditions and in upland washed BRH sediment are presented below:

Heavy Metal	Concentration, $\mu\text{g/g}$		
	Original Sediment		Washed Sediment, Upland
	Flooded	Upland*	
Zinc	13.0	219	341
Cadmium	0.04	0.91	4.65
Copper	3.77	18.7	36.2
Chromium	0.02	0.93	2.79
Lead	0.39	1.53	2.53

* Only one replicate supported plant growth.

Spartina alterniflora grew well and had low heavy metal contents under the flooded conditions. These results are typical for contaminated saltwater sediment placed under a flooded condition, and the data compared well with levels observed in plants from natural saltmarshes (Simmers et al. 1981). *S. alterniflora* did not grow well in the original air-dried (upland) sediment:

and

$$V_{\text{sediment}} = 3.75 \frac{C_{\text{slurry}}}{C_{\text{sediment}}} \quad (1)$$

$$V_{\text{water}} = 3.75 - V_{\text{sediment}} \quad (2)$$

where

V_{sediment} = volume of sediment, liters

3.75 = volume of slurry for 4-l cylinder, liters

C_{slurry} = desired concentration of slurry, grams per liter
(dry-weight basis)

C_{sediment} = predetermined concentration of sediment, grams per liter
(dry-weight basis)

V_{water} = volume of dredging site water, liters

Step 2 - Mixing. Mix the 3-3/4 l of slurry by placing appropriate volumes of sediment and dredging site water in 1-gal glass jars and mixing for 5 min with a laboratory mixer. The slurry should be mixed to a uniform consistency with no unmixed agglomerations of sediment.

Step 3 - Aeration. Bubble aeration is used to ensure oxidizing conditions in the supernatant water during the subsequent settling phase. Pour the mixed slurry into a 4-l graduated cylinder. Attach glass tubing to the aeration source and insert tubing to the bottom of the cylinder. The tubing can be held in place by insertion through a predrilled No. 4 stopper placed in the top of the cylinder. Compressed air should be passed through a deionized water trap, through the tubing, and bubbled through the slurry. The flow rate should be adjusted to agitate the mixture vigorously, and bubbling should be continued for 1 hr.

Step 4 - Settling. Remove the tubing and allow the aerated slurry to undergo quiescent settling for a time period equal to the anticipated field mean retention time up to a maximum of 24 hr. If the field mean retention time is not known, allow settling for 24 hr. Guidance for estimating the field mean retention is given in Technical Note EEDP-04-3.

Step 5 - Sample extraction. After the settling period, an interface will usually be evident between the supernatant water with low concentration of suspended solids and the more concentrated settled material. Samples of the supernatant water should be extracted from the cylinder at a point midway between the water surface and the interface using syringe and tubing. Care should be taken not to resuspend settled material.

Test procedure

The step-by-step procedure for conducting a modified elutriate test, as shown in Figure 1, is given in the following paragraphs.

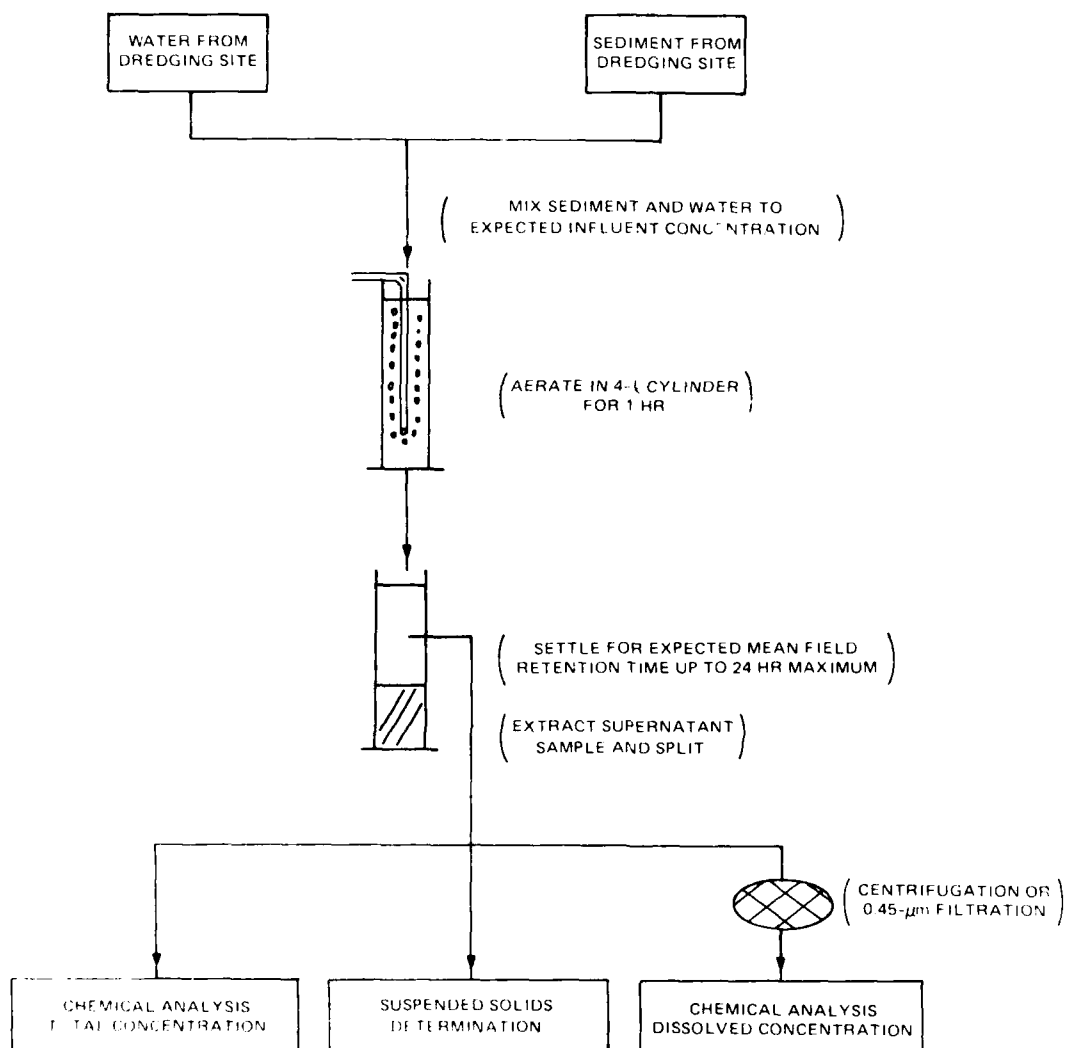


Figure 1. Modified elutriate test procedure

Step 1 - Slurry preparation. The sediment and dredging site water should be mixed to approximately equal the expected average field inflow concentration. If estimates of the average field inflow concentration cannot be made based on past data, a slurry concentration of 150 g/l (dry-weight basis) should be used. Predetermine the concentration of the well-mixed sediment in grams per liter (dry-weight basis) by oven drying a small subsample of known volume. Each 4-l cylinder to be filled will require a mixed slurry volume of 3-3/4 l. The volumes of sediment and dredging site water to be mixed for a 3-3/4-l slurry volume can be calculated using the following expressions:

number and types of analyses to be conducted (Plumb 1981). Both dissolved and total concentrations of contaminants must be determined. The volume required for each analysis, the number of parameters measured, and the desired analytical replication will influence the total elutriate sample volume required. A 4-l cylinder is normally used for the test, and the supernatant volume available for sample extraction will vary from approximately 500 to 1,000 ml, depending on the sediment properties, settling times, and initial concentration of the slurry. It may be necessary to composite several extracted samples or use large-diameter cylinders to obtain the total required volume.

Apparatus

The following items are required:

- a. Laboratory mixer, preferably with Teflon shaft and blades.
- b. Several 4-l graduated cylinders. Larger cylinders may be used if large sample volumes are required. Nalgene cylinders are acceptable for testing involving analysis of metals and nutrients. Glass cylinders are required for testing involving analysis of organics.
- c. Assorted glassware for sample extraction and handling.
- d. Compressed air source with deionized water trap and tubing for bubble aeration of slurry.
- e. Vacuum or pressure filtration equipment, including vacuum pump or compressed air source and appropriate filter holder capable of accommodating 47-, 105-, or 155-mm-diam filters.
- f. Presoaked filters with 0.45- μ m pore-size diameter.
- g. Plastic sample bottles, 500-ml capacity for storage of water and liquid phase samples for metal and nutrient analyses.
- h. Wide-mouth 1-gal-capacity glass jars with Teflon-lined screw-type lids for sample mixing. These jars should also be used as sample containers when samples are to be analyzed for pesticide materials.

Prior to use, all glassware, filtration equipment, and filters should be thoroughly cleaned. Wash all glassware with detergent; rinse five times with tap water; place in a clean 10-percent (or stronger) HCl acid bath for a minimum of 4 hr; rinse five times with tap water; and then rinse five times with distilled or deionized water. Soak filters for a minimum of 2 hr in a 5-M HCl bath and then rinse 10 times with distilled water. It is also a good practice to discard the first 50 ml of water or liquid phase filtered. Wash all glassware to be used in preparation and analysis of pesticide residues using the eight step procedure given EPA (1980a).

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant content is particle associated. The modified elutriate test was developed for use in predicting both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980b). Proposed testing requirements define dredged material according to four categories. Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of the short-term water-column impacts of disposal area effluents. Predicted contaminants levels based on results of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

ADDITIONAL INFORMATION: Contact the author, Dr. Michael R. Palermo (601) 634-3753 (FTS 542-3753), or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler (601) 634-3624 (FTS 542-3624).

Initial Screening

An initial screening for contamination must be performed as outlined in the testing requirements for Section 404 of the Clean Water Act (EPA 1980b). The evaluation is designed to determine if there is reason to believe that the sediment contains any contaminant at a significant concentration (above background levels) and to identify the contaminants of concern that should be considered for analysis in the modified elutriate test. Considerations include but are not limited to:

- a. Potential routes by which contaminants could reasonably have been introduced to the sediment.
- b. Data from previous tests of the sediment or other similar sediment in the vicinity, provided comparison would still be appropriate.
- c. Probability of contamination from surface runoff.
- d. Spills of contaminants in the area to be dredged.
- e. Industrial and municipal waste discharges.

Modified Elutriate Test

The modified elutriate test should be conducted and appropriate chemical analyses should be performed as soon as possible after sample collection. The volume of elutriate recommended for chemical analyses will depend on the



Environmental Effects of Dredging Technical Notes



INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--TEST PROCEDURES

PURPOSE: The following series of technical notes describe the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during dredging operations.*

EEDP-04-1	General
EEDP-04-2	Test Procedures
EEDP-04-3	Data Analysis
EEDP-04-4	Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operations (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluations of predictions and field measurement of effluent water quality.

BACKGROUND: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas during disposal operations (effluent) is a major environmental concern associated with such disposal.

Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (called supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

* The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal site.

Notations

The notations used in Technical Notes EEDP-04-1 through 4 are defined as follows.

A_p	Area ponded, acres
C_{diss}	Dissolved concentration of constituent, milligrams per liter
C_i	Inflow solids concentration, grams per liter
C_{slurry}	Solids concentration of slurry, grams per liter (dry weight basis)
$C_{sediment}$	Solids concentration of sediment, grams per liter (dry weight basis)
C_{total}	Total concentration of constituent, milligrams per liter
F_{SS}	Fraction of constituent in total suspended solids, milligrams per kilogram
D_p	Depth of ponding in disposal site, ft
D_{pw}	Desired ponding depth or ponding depth at weir, ft
HEF	Hydraulic efficiency factor
Q_i	Inflow rate, cubic feet per second
P	Percent of suspended solids remaining at test interval
R	Percent of solids removed from suspension at test interval
RF	Resuspension factor
SS	Total suspended solids concentration, milligrams per liter
SS_{col}	Suspended solids concentration determined by column test, milligrams per liter
SS_{eff}	Suspended solids concentration of effluent considering anticipated resuspension, milligrams per liter of water
T	Theoretical detention time, hours
T_d	Field mean detention time, hours
t	Sampling time, hr
$V_{sediment}$	Volume of sediment, cubic feet
V_p	Volume ponded, cubic feet
V_{water}	Volume of water, cubic feet
z	Sampling depth, ft
ϕ	Percent of initial suspended solids concentration (beginning of column test) that is retained as 100 percent)

References

Environmental Effects Laboratory. 1976. "Ecological Evaluation of Proposed Discharges of Dredged Material into Navigable Water," Miscellaneous Paper D-76-17, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Environmental Protection Agency. 1980a. "Guidelines for Specification of Disposal Sites for Dredged or Fill Material," Federal Register, Vol. 45, No. 249, pp 85336-85358.

Environmental Protection Agency. 1980b. "Testing Requirements for the Specification of Disposal Sites for Dredged or Fill Material," Federal Register, Vol. 45, No. 249, pp 85359-85367.

Environmental Protection Agency/Corps of Engineers. 1977. "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Water, Implementation Manual for Section 103 of Public Law 95-532 (Marine Protection, Research, and Sanctuaries Act of 1972)," US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Montgomery, R. L. 1978. "Methodology for Design of Fine-Grained Dredged Material Containment Areas for Solids Retention," Technical Report D-78-56, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Palermo, M. R., Montgomery, R. L., and Poindexter, M. 1978. "Guidelines for Designing, Operating, and Managing Dredged Material Containment Areas," Technical Report DS-78-10, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Plumb, R. H. 1981. "Procedures for Handling and Chemical Analysis of Sediment and Water Samples," EPA/CE Technical Committee on Criteria for Dredged and Fill Material, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Application

The technique for predicting the quality of effluent discharged from confined dredged material disposal areas is described in Technical Note EEDP-04-3. The technique can be applied to predict the performance of existing sites or to design new sites.

For existing sites, the technique can be used to predict effluent quality for a given set of anticipated operational conditions (known flow and ponding conditions). In a similar manner, the procedure can be used to determine the operational conditions (size, geometry, maximum allowable dredge size, etc.) for a proposed site to meet a given effluent quality requirement. Examples of both of these cases are presented in Technical Note EEDP-04-4.

Table 1
Data Requirements for Predicting the Quality of Effluent
from Confined Dredged Material Disposal Area*

<u>Data Required</u>	<u>Symbol</u>	<u>Source of data</u>
Dredge inflow rate	Q_i	Project information, site design
Dredge inflow solids concentration	C_i	Project information, site design
Ponded area in disposal site	A_p	Project information, site design
Average ponding depth in disposal site and at the weir	D_p, D_{pw}	Project information, site design
Hydraulic efficiency factor	HEF	Dye tracer or theoretical determination
Effluent total suspended solids concentration	SS_{eff}	Column settling tests
Dissolved concentration of contaminant in effluent	C_{diss}	Modified elutriate tests
Fraction of contaminant in the total suspended solids in effluent	F_{SS}	Modified elutriate tests

* This summary includes only those data required for effluent quality prediction. It was assumed that the disposal area under consideration was designed for effective sedimentation and storage capacity. Data requirements for design or evaluation of a disposal area are found in Palermo, Montgomery, and Poindexter (1978).

number of sampling stations, quantity of material, and any scheme used for compositing samples, is highly project specific. If at all possible, the sampling operations required for sediment characterization (both physical and chemical), for design or evaluation of the disposal site, and for modified elutriate and column settling tests should be conducted simultaneously to avoid duplication of effort and to ensure sample similarity.

Normally effluent quality will be of concern for maintenance dredged material. Representative samples of sediments proposed for maintenance dredging are satisfactory for obtaining the quantities needed for all testing requirements. General guidance on sampling for chemical characterization purposes is found in Plumb (1981). This reference should be used for guidance in obtaining samples for use in the modified elutriate testing.

(i.e., surface area, ponding depth, inflow rate, and hydraulic efficiency).

Using results from both of these tests, a prediction of the total concentration of contaminants in the effluent can be made. A flow chart illustrating the technique is shown in Figure 3. The procedures for conducting both tests are given in Technical Note EEDP-04-2.

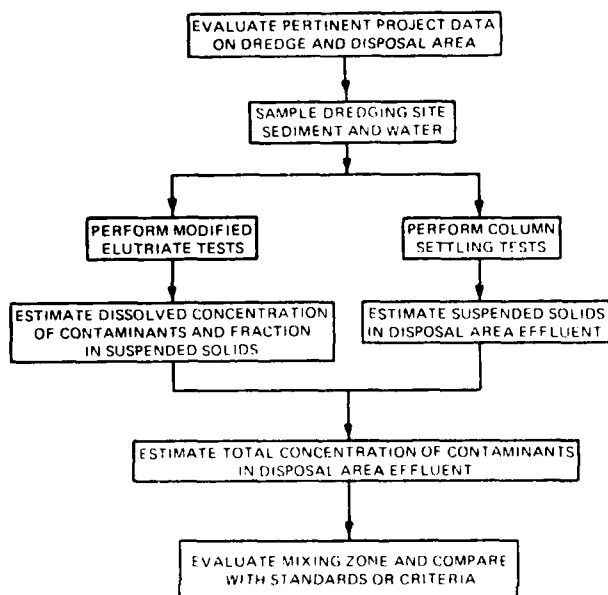


Figure 3. Steps for predicting effluent water quality

in dredging and disposal activities for the project under consideration or for similar projects. Data relating to the characteristics of the sediment must be determined from samples of the sediment to be dredged and the dredging site water column.

A summary of the data requirements for effluent quality predictions is given in Table 1. Some of the data can be determined from the design or from evaluation of the site using procedures described by Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978). The remaining data must be developed using the procedures described in Technical Note EEDP-04-2.

Data Requirements

Data requirements for prediction of effluent quality include those pertaining to operational considerations (i.e., disposal site characteristics and dredge characteristics) and those pertaining to the properties of the sediment to be dredged (i.e., contaminant-release characteristics and sedimentation characteristics). Data relating to operational considerations are usually determined from the disposal area design and by past experience

Sampling Requirements

Samples of sediment and water from a proposed dredging site are required for characterizing the sediment to be dredged and for conducting modified elutriate tests and column settling tests. The level of effort, including the

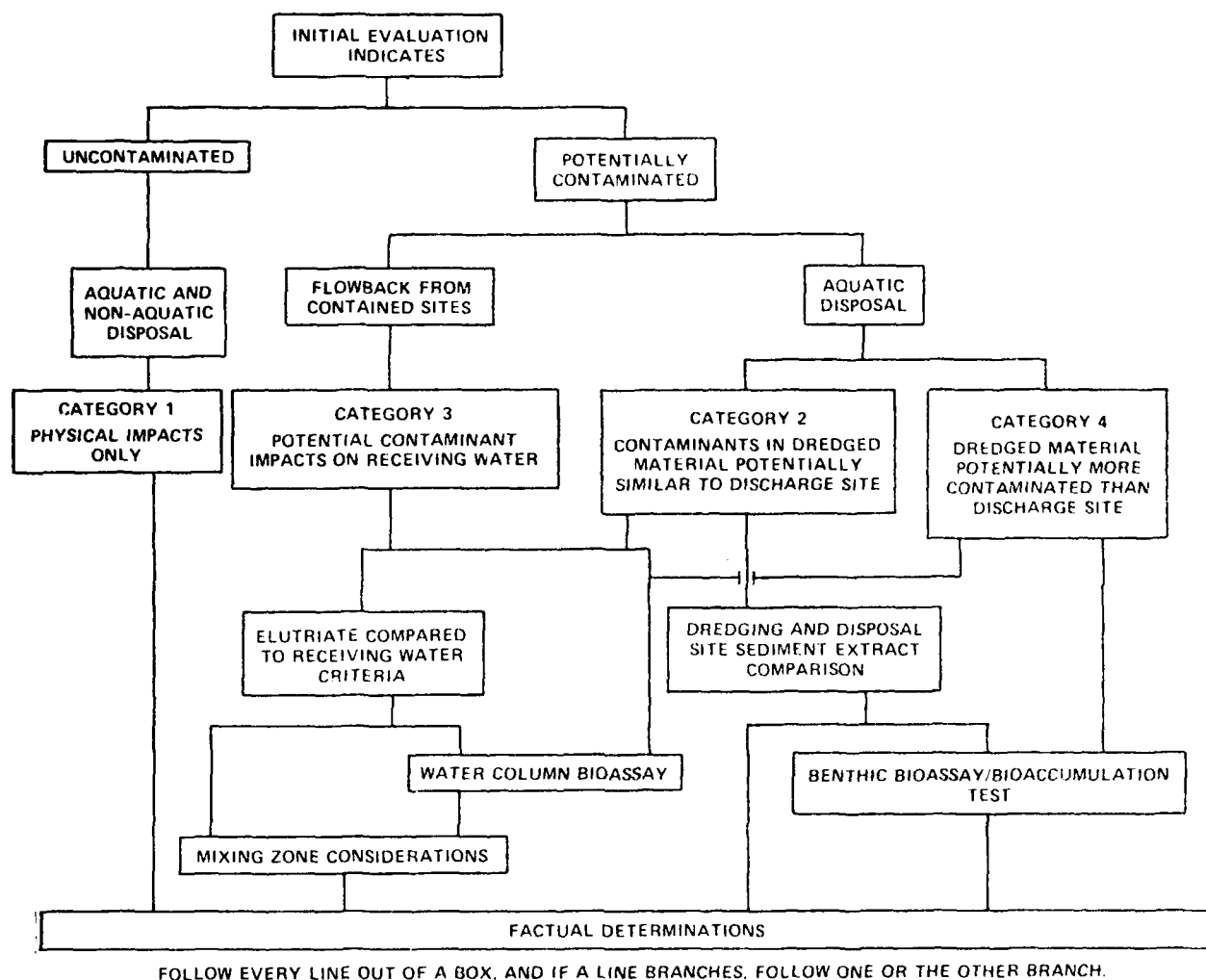


Figure 2. Proposed dredged material regulatory testing flow chart (EPA 1980b)

Predictive Technique

The prediction of the quality of effluent from confined dredged material disposal areas must account for both the dissolved concentrations of contaminants and that fraction in the total suspended solids. A modified elutriate test procedure, developed for this purpose, defines dissolved concentrations of contaminants and contaminant fractions in the total suspended solids under quiescent settling conditions and accounts for the geochemical changes occurring in the disposal area during active disposal operations. Column settling test procedures (Montgomery 1978; Palermo, Montgomery, Poindexter 1978) were refined and extended to define the concentration of suspended solids in the effluent for given operational conditions

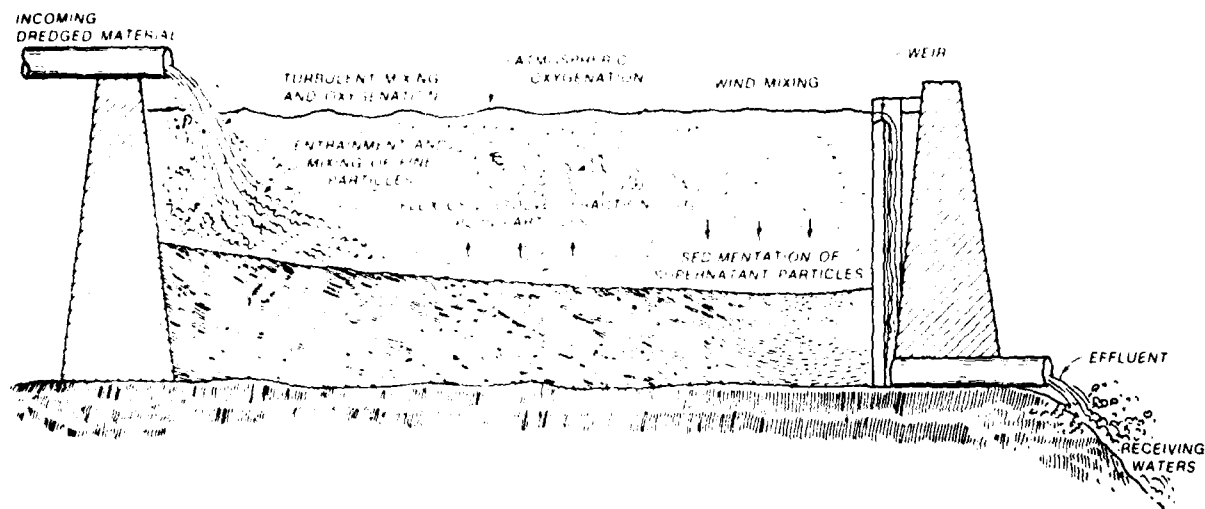


Figure 1. Schematic of factors affecting quality of effluent from confined disposal areas

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant level is particle associated. Results of the standard elutriate test do not reflect the conditions in confined disposal sites that influence contaminant release. A modified elutriate test procedure was therefore developed for use in predicting both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas. The modified test simulates contaminant release under confined disposal area conditions and reflects the sedimentation behavior of dredged material, retention time of the disposal area, and chemical environment in ponded water during disposal.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980a). Proposed testing requirements define dredged material according to the four categories shown in Figure 2 (EPA 1980b). Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of short-term water column impacts of disposal area effluents. Predicted contaminant levels based on results of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

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Environmental Effects of Dredging Technical Notes



INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--GENERAL

PURPOSE: The following series of technical notes describe the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during disposal operations.*

EEDP-04-1	General
EEDP-04-2	Test Procedures
EEDP-04-3	Data Analysis
EEDP-04-4	Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operations (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluations of predictions and field measurement of effluent water quality.

BACKGROUND: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas (effluent) is a major environmental concern associated with such disposal.

A schematic of a typical active confined disposal area is illustrated in Figure 1. Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

* The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal site.

only one plant of one replicate survived. Decreased plant growth resulting in increased metal content could explain the elevated heavy metal content of the plant. Plants grown in washed sediment under an upland condition grew much better than under the unwashed upland condition. However, the heavy metal content of the plants was much greater compared to that of plants grown in the flooded condition. The same effect has been shown by Folsom and Lee (1981b) to occur with freshwater plants grown in freshwater sediment under flooded and upland disposal environments. Apparently, once the saltwater sediment is washed free of excess salt and plant growth occurs, the air-drying process results in increased availability of heavy metals. Removing excess salt from the sediment by washing simulated the natural salt-leaching process and can be used in a modified saltwater solid-phase plant bioassay to predict contaminant mobility into plants growing on saltwater dredged material deposited in upland disposal sites.

References

- Folsom, B. L., Jr., and Lee, C. R. 1981a. "Development of a Plant Bioassay for Determining Toxic Metal Uptake from Dredged and/or Fill Material," Proceedings, International Conference, Heavy Metals in the Environment (Amsterdam), CEP Consultants, Ltd., 26 Albany Street, Edinburgh, Scotland EH1 3QH, United Kingdom, pp 417-420
- Folsom, B. L., Jr., and Lee, C. R. 1981b. "Zinc and Cadmium Uptake by the Freshwater Marsh Plant *Cyperus esculentus* Grown in Contaminated Sediments Under Reduced (Flooded) and Oxidized (Upland) Disposal Conditions," Journal of Plant Nutrition, 3:233-244.
- Folsom, B. L., Jr., and Lee, C. R. 1983. "Contaminant Uptake by *Spartina alterniflora* from an Upland Dredged Material Disposal Site - Application of a Saltwater Plant Bioassay," Proceedings, International Conference, Heavy Metals in the Environment (Heidelberg), CEP Consultants, Ltd., 26 Albany Street, Edinburgh, Scotland EH1 3QH, United Kingdom, 1:646-648.
- Folsom, B. L., Jr., Lee, C. R., and Bates, D. J. 1981. "Influence of Disposal Environment on Availability and Plant Uptake of Heavy Metals in Dredged Material," Technical Report EL-81-12, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Lee, C. R., Folsom, B. L., Jr., and Engler, R. M. 1982. "Availability and Plant Uptake of Heavy Metals from Contaminated Dredged Material Placed in Flooded and Upland Disposal Environments," Environment International, 7:65-71.
- Simmers, J. W., Folsom, B. L., Jr., Lee, C. R., and Bates, D. J. 1981. "Field Survey of Heavy Metal Uptake by Naturally Occurring Saltwater and Freshwater Marsh Plants," Technical Report EL-81-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Step 6 - Sample preservation and analysis. The sample should be analyzed as soon as possible after extraction to determine the total suspended solids and the dissolved and total concentrations of selected constituents. The fraction of a constituent in the total suspended solids can then be calculated. Filtration using 0.45- μ m filters should be used to obtain subsamples for analysis of dissolved concentrations. Samples to be analyzed for dissolved pesticides or PCB must be free of particles but should not be filtered, due to the tendency for these materials to adsorb on the filter. However, particulate matter can be removed before analysis by high-speed centrifugation at 10,000 times gravity using Teflon, glass, or aluminum centrifuge tubes (Fulk et al. 1975). The total suspended solids concentration can also be determined by filtration (0.45 μ m). The fraction of a constituent in the total suspended solids is calculated as follows:

$$F_{SS} = (1 \times 10^6) \frac{C_{total} - C_{diss.}}{SS} \quad (3)$$

where

- F_{SS} = fraction of constituent in the total suspended solids, milligrams per kilogram of suspended solids
- C_{total} = total concentration of constituent, milligram per liter of sample
- $C_{diss.}$ = dissolved concentration of constituent, milligrams per liter of sample
- SS = total suspended solids concentration, milligrams per liter of sample

Subsamples for analyses of total concentrations should undergo appropriate digestion prior to analysis. All digestion and chemical analyses should be performed using accepted procedures (American Public Health Association 1985; EPA 1980a; and EPA 1979).

Samples to be analyzed for pesticides or PCB should immediately undergo solvent extraction. The extract may then be held in clean uncontaminating containers for periods up to three or four weeks at -15 to -20° C before further analyses are performed.

Samples for metals analysis should be preserved immediately by lowering the pH to <2 with 3 to 5 ml of concentrated nitric acid per liter (EPA 1979). High purity acid, either purchased commercially or prepared in a subboiling unit, must be used.

Nutrient analyses should be conducted as soon as possible. Acidification with H_2SO_4 to $\text{pH} < 2$ and storage at 4°C will allow the sample to be held for maximum of 24 hr for ammonia nitrogen, Kjeldahl nitrogen, and nitrate nitrogen analyses (EPA 1979). Storage at 4°C will allow holding of samples to be analyzed for dissolved orthophosphate and total dissolved phosphorus for up to 24 hr. Subsamples to be analyzed for cyanide should be preserved with 2 ml of 10 N sodium hydroxide per liter of sample ($\text{pH} > 12$) (EPA 1979).

Column Settling Test

Sedimentation tests, performed in 8-in.-diam ported columns as shown in Figure 2, are necessary to provide data for design or evaluation of disposal areas for retention of suspended solids. These tests were originally designed to define the settling behavior of a particular sediment and to provide information concerning the volumes occupied by newly placed layers of dredged material. The test procedures were modified to obtain data for use in predicting the concentration of suspended solids in the effluent.

Sedimentation of freshwater slurries of solids concentration less than 100 g/l can generally be characterized by flocculent settling properties. As solids concentrations exceed 100 g/l, the sedimentation process may be characterized by zone settling properties in which a clearly defined interface is formed between the clarified supernatant water and the more concentrated settled material. Zone settling properties also govern when the sediment/water salinity is greater than 3 ppt. Recent studies have shown that flocculent settling governs behavior of suspended solids in the clarified supernatant water above the sediment/water interface for slurries exhibiting an interface.

Apparatus

A settling column such as shown in Figure 2 is used. The test column depth should approximate the effective settling depth of the proposed disposal area. A practical limit on the depth of test is 6 ft. The column should be at least 8 in. in diameter with interchangeable sections and with sample port at 1-ft or closer intervals in the lower 3 ft and at 1/2-ft intervals in the upper 3 ft. The column should have provisions to bubble air from the bottom to keep the slurry mixed during the column filling period. Shop drawings for construction of the test columns are available from the Waterways Experiment Station.*

* Address request for the shop drawings to the attention of WISEP-E.

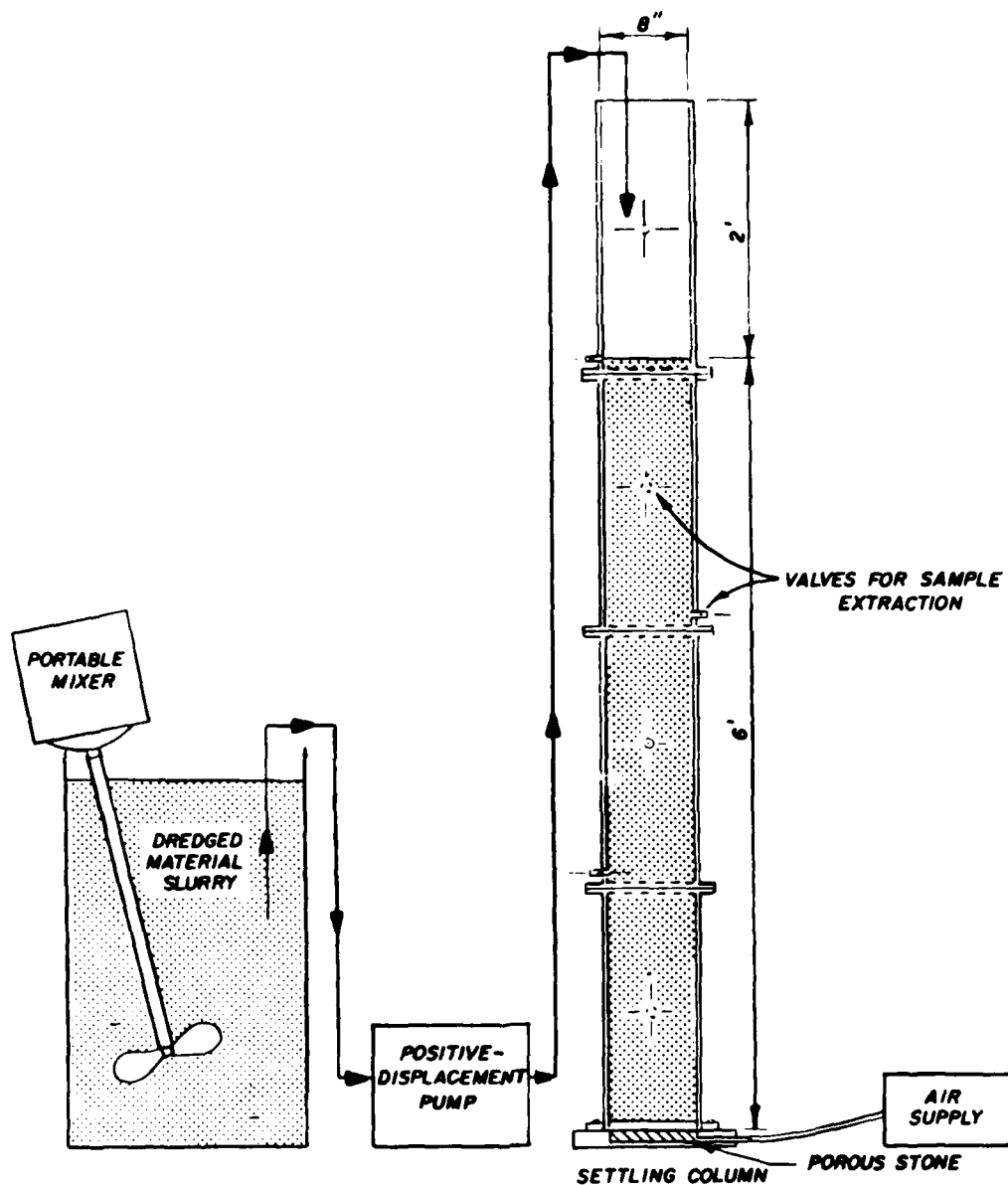


Figure 2. Schematic of apparatus for column settling tests (Montgomery 1978)

Flocculent settling test

Test data required to design or evaluate a disposal area in which flocculent settling governs and to predict the concentration of suspended solids in the effluent can be obtained using procedures described by Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978). The flocculent settling test consists of withdrawing samples from each sample port at regular time intervals to determine the concentration of suspended solids at various depths.

Zone settling test

Information required to design or evaluate a disposal area in which zone settling governs can be obtained by conducting a series of zone settling tests (Montgomery 1978 and Palermo, Montgomery, and Poindexter 1978). One of the tests should be performed on sediment slurries at a concentration equal to the expected mean field inflow concentration. This test should be continued for a period of at least 15 days to provide data for estimating volume requirements and to obtain data for prediction of effluent suspended solids concentrations.

The procedures described below include those modifications of the procedures described by Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978) required to define the flocculent process governing the sedimentation of suspended solids above the interface. The flocculent settling test as modified consists of measuring the concentration of suspended solids at various depths and time intervals by withdrawing samples from the settling column and timing the fall of liquid/solids interface.

Step 1 - Slurry preparation and loading. Mix the sediment slurry to the desired suspended solids concentration in a container with sufficient volume to fill the test column. The test should be performed at the concentration C_i selected to represent the anticipated concentration of the dredged material influent. Field studies indicate that for maintenance dredging in fine-grained material, the disposal concentration will average about 150 g/l. This value may be used for C_i if no better data are available.

Step 2 - Settling and sampling. For sediments exhibiting zone settling behavior, an interface will form between the more concentrated settled material and the clarified supernatant water. The first sample should be extracted immediately after the interface has fallen sufficiently below the uppermost port to allow extraction. This sample can usually be extracted within a few hours after initiation of the test, depending on the initial slurry concentration and the spacing of ports.

As the interface continues to fall, extract samples from all ports above the interface at regular time intervals. Substantial reductions of suspended solids will occur during the early part of the test, but reductions will lessen at longer retention times. Therefore, the intervals can be extended as the test progresses. A suggested sequence of intervals would be 2, 4, 8, 12, 24, 48, 96 hr, etc. Continue to take samples throughout the 15-day test or until the suspended solids concentration of the extracted samples shows no decrease. Record the time of extraction and the port height for each port sample taken (Figure 3).

COLUMN SETTLING DATA				
(1) TIME t HR	(2) SAMPLE DEPTH z FT	(3) TOTAL SUSPENDED SOLIDS SS mg/l	(4) PERCENT OF INITIAL CONCENTRATION ϕ	
3	0.2	93		
	1.0	169		
7	1.0	100		
	2.0	105		
14	1.0	45		
	2.0	43		
	3.0	50		
24	1.0	19		
	2.0	18		
	3.0	20		
48	1.0	15		
	2.0	7		
	3.0	4		

References

- American Public Health Association (APHA). 1985. Standard Methods for the Examination of Water and Wastewater, 16th ed., American Water Works Association, Water Pollution Control Federation, APHA, Washington, DC.
- Environmental Effects Laboratory. 1976. "Ecological Evaluation of Proposed Discharge of Dredged Material into Navigable Water," Miscellaneous Paper D-76-17, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Environmental Protection Agency. 1979. "Methods for Chemical Analysis of Water and Wastes," EPA 600/4-79-020, Office of Technology Transfer, Washington, DC.
- Environmental Protection Agency. 1980a. "Analysis of Pesticide Residues in Human and Environmental Samples," EPA 600/8-80-038, Environmental Toxicology Division, Research Triangle Park, N.C.
- Environmental Protection Agency. 1980b. "Guidelines for Specification of Disposal Sites for Dredged or Fill Material," Federal Register, Vol 45, No. 249, 24 December 1980, pp 85336-85358.
- Environmental Protection Agency/Corps of Engineers. 1977. "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters; Implementation Manual for Section 103 of Public Law 92-532 (Marine Protection, Research, and Sanctuaries Act of 1972)," US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Fulk, R., et al. 1975. "Laboratory Study of the Release of Pesticide and PCB Materials to the Water Column During Dredging and Disposal Operations," Contract Report No. D-75-6, prepared by Envirex, Inc., Milwaukee, Wisconsin, under contract to the US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Montgomery, R. L. 1978. "Methodology for Design of Fine-Grained Dredged Material Containment Areas for Solids Retention," Technical Report D-78-56, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Palermo, M. R., Montgomery, R. L., and Poindexter, M. 1978. "Guidelines for Designing, Operating, and Managing Dredged Material Containment Areas," Technical Report DS-78-10, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Plumb, R. H. 1981. "Procedures for Handling and Chemical Analysis of Sediment Water Samples," EPA/CE Technical Committee on Criteria for Dredged and Fill Material, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.



Environmental Effects of Dredging Technical Notes



INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--DATA ANALYSIS

PURPOSE: The following series of technical notes described the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during dredging operations.*

EEDP-04-1	General
EEDP-04-2	Test Procedures
EEDP-04-3	Data Analysis
EEDP-04-4	Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operation (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluation of predictions and field measurement of effluent water quality.

BACKGROUND: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas during disposal operations (effluent) is a major environmental concern associated with such disposal.

Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (called supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant content is particle associated. The modified elutriate tests were developed for use in predicting

* The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal sites.

both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980). Proposed testing requirements define dredged material according to four categories. Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of the short-term water column impacts of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

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Data Analysis

The results of the column settling tests are used to determine the concentrations of suspended solids in the effluent from a confined disposal site.

Sedimentation of freshwater slurries with solids concentrations of less than 100 g/l are generally characterized by flocculent settling properties. When solids concentrations exceed 100 g/l, the sedimentation process may be characterized by zone settling properties in which a clearly defined interface is formed between the clarified supernatant water and the more concentrated settled material. Zone settling properties also govern when the sediment/water salinity is greater than 3 ppt. Recent studies have shown that flocculent settling governs behavior of the suspended solids in the clarified supernatant water above the sediment/water interface for slurries exhibiting an interface.

For the flocculent case, the procedures for data analysis given in Montgomery (1973) and Palermo, Montgomery, and Poindexter (1978) may be used. For the zone settling case, flocculent settling behavior governs in the supernatant water above the interface. Therefore, a modified flocculent data analysis procedure as outlined in the following paragraphs is required. Example calculations are given in Technical Note EEDP-04-4.

Step 1. Compute values of z , the depth of sampling below the fluid surface as shown in Figure 1. In computing ϕ , the fraction remaining, the highest concentration of the first port samples is considered the initial concentration SS_0 .

Step 2. Plot the values of fractions remaining ϕ and z using column settling data to form a concentration profile diagram (Figure 2). Concentration profiles should be plotted for each time of sample extraction.

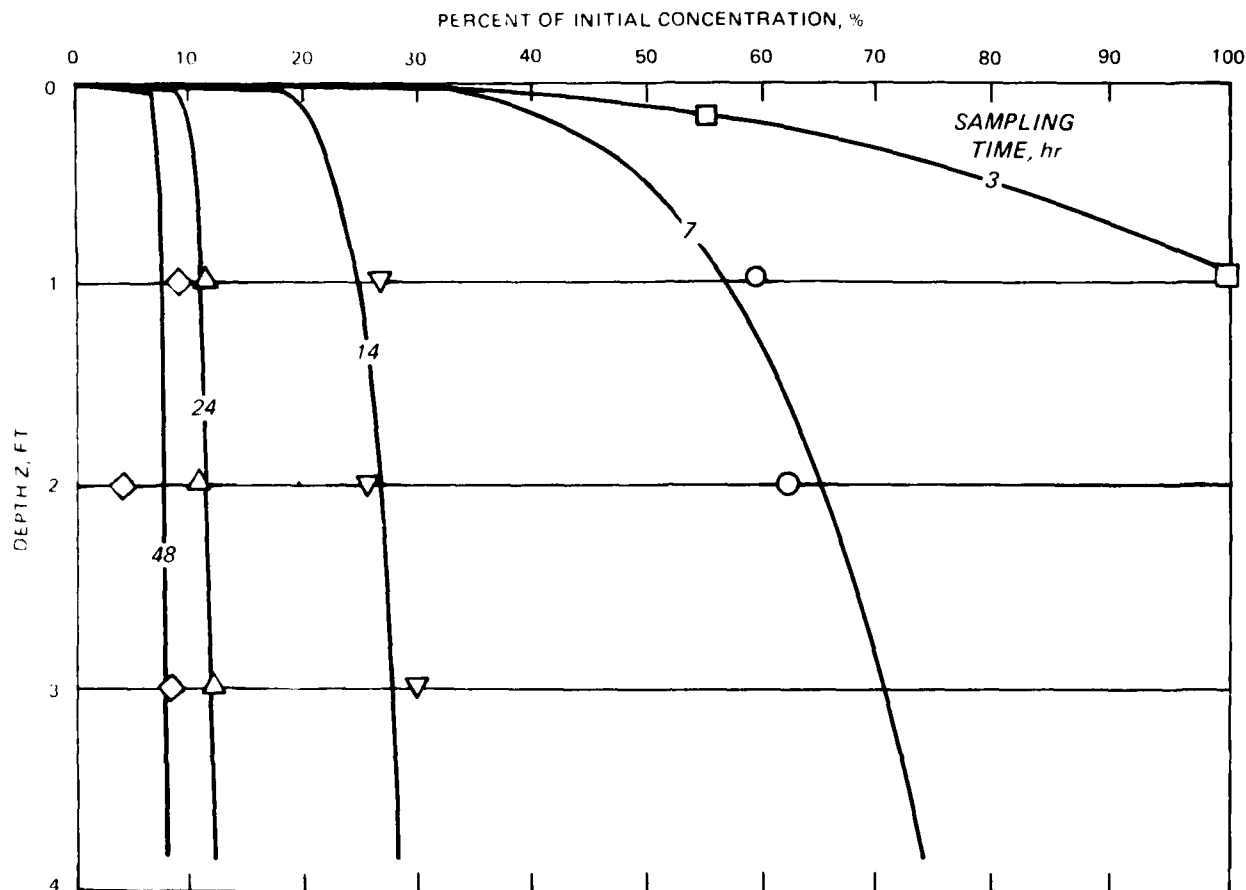


Figure 2. Concentration profile diagram

Step 3. Use the concentration profile diagram to graphically determine R , the percentages of solids removed for the various time intervals for any desired ponding depth D_{pw} . This is done by determining the area to the right of each concentration profile and its ratio to the total area above the depth D_{pw} . The removal percentage R is calculated as follows:

$$R = \frac{\text{Area Right of Profile}}{\text{Total Area}} 100 \quad (1)$$

Step 4. Compute P , the percentage of suspended solids remaining in suspension, as simply 100 minus the percentage removed as follows:

$$P = 100 - R \quad (2)$$

Step 5. Compute values for suspended solids for each time of extraction as follows:

$$SS = P \times SS_0 \quad (3)$$

Tabulate R , and P , and SS for each sampling time.

Step 6. Plot a relationship for suspended solids concentration versus time using the value for each sampling time (Figure 3). An exponential or power curve fitted through the data points is recommended.

By repeating steps 4 through 6 for each of several values of D_{pw} , a family of curves showing suspended solids versus retention time for each of several ponding depths can be developed as shown in Figure 3. These curves can be used for prediction of effluent suspended solids concentrations under quiescent settling conditions for any estimated ponding depth and field mean retention time. Simply enter a curve with the estimated field mean retention time T_d and select the value of suspended solids as estimated from the column test SS_{col} . Guidance for adjusting the value derived from the column test for anticipated resuspension and for estimated field mean retention time is given in the following paragraphs.

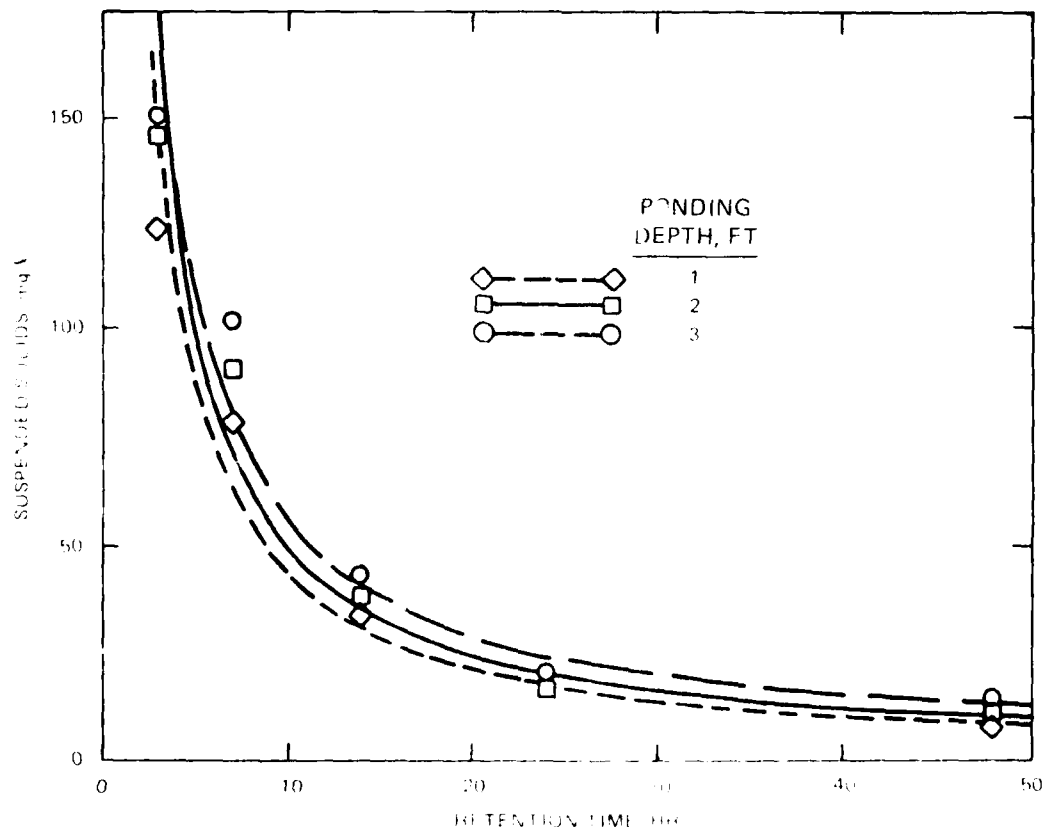


Figure 3. Supernatant suspended solids concentration versus time from column settling test

Effluent Suspended Solids Concentration

A prediction of the concentration of total suspended solids in the effluent must consider the anticipated retention time in the disposal area and must account for the possible resuspension of settled material because of wind effects. The relationship of supernatant suspended solids versus time developed from the column settling test is based on quiescent settling conditions found in the laboratory. The anticipated retention time in the disposal area under consideration can be used to determine a predicted suspended solids concentration from the relationship. This predicted value can be considered a minimum value that could be achieved in the field assuming little or no resuspension of settled material.

For dredged material exhibiting flocculent settling behavior, the concentration of particles in the ponded water is on the order of 1 g/l or higher. The resuspension resulting from normal wind conditions will not significantly increase this concentration; therefore, an adjustment for resuspension is not required for the flocculent settling case.

However, an adjustment for anticipated resuspension is appropriate for dredged material exhibiting zone settling. The minimum expected value and the value adjusted for resuspension provide a range of anticipated suspended solids concentrations for use in predicting the total concentrations of contaminants in the effluent.

The following tabulation summarizes recommended resuspension factors (RF) based on comparisons of suspended solids concentrations as predicted from column settling tests and field data from a number of sites with various site conditions.

Anticipated Ponded Area acres	Resuspension Factor- Average Ponded Depth	
	Less than 2 ft	2 ft or Greater
Less than 100	2.0	1.5
Greater than 100	2.5	2.0

The value of SS_{eff} , suspended solids concentration of the effluent considering anticipated resuspension, is calculated using equation 4.

$$SS_{eff} = SS_{col} \times RF \quad (4)$$

where

SS_{eff} = suspended solids concentration of effluent considering anticipated resuspension, milligrams per liter of water

SS_{col} = suspended solids concentration of effluent estimated from column settling tests, milligrams per liter of water

RF = resuspension factor

Field Mean Retention Time

Estimates of the field mean retention time for expected operational conditions are required for selecting appropriate settling times in the modified elutriate test and for determination of suspended solids concentrations in the effluent. Estimates of the retention time must consider the hydraulic efficiency of the disposal area, defined as the ratio of mean retention time to theoretical retention time. Field mean retention time T_d can be estimated for given flowrate and ponding conditions by applying a hydraulic efficiency factor to the theoretical detention time T as follows:

$$T_d = \frac{T}{HEF} \quad (5)$$

where

T_d = mean detention time, hr

T = theoretical detention time, hr

HEF = hydraulic efficiency factor (HEF > 1.0) defined as the inverse of the hydraulic efficiency

The theoretical detention time is calculated as follows:

$$T = \frac{V_p}{Q_i} (12.1) = \frac{A_p D_p}{Q_i} (12.1) \quad (6)$$

where

T = theoretical detention time, hr

V_p = volume ponded, acre-ft

Q_i = average inflow rate, cfs

A_p = area ponded, acres

D_p = average depth on ponding, ft

12.1 = conversion factor acre ft/cfs to hr

The hydraulic efficiency factor HEF can be estimated by several methods. The most accurate estimate for existing sites is made from field dye-tracer data previously obtained at the site under operational conditions similar to those for the operation under consideration. Guidance for conducting such field tests is presented by Schroeder et al. (in preparation).

Hydraulic flow models can also be used to evaluate the efficiency factor. Koussis, Saenz, and Thackston* recommended steady-state two-dimensional models for such evaluations. Development of such techniques is still under study (Schroeder et al. in preparation).

In absence of dye-tracer data or values obtained from other theoretical approaches, the HEF can be assumed based on values obtained by dye-tracer studies at similar sites and under similar conditions. Montgomery (1978) recommended at a value for HEF of 2.25 based on field studies conducted at several sites.

Total Concentrations of Contaminants

For each contaminant of interest, the modified elutriate test procedure defines the dissolved concentration and the fraction of the particle-associated contaminant in the total suspended solids under quiescent settling conditions and accounts for geochemical changes occurring in the disposal area during active disposal operations. Using these test results in conjunction with those from column settling tests, the total concentration of the contaminant in the effluent can be determined based on the estimated sedimentation condition as follows:

$$C_{\text{total}} = C_{\text{diss.}} + \frac{F_{\text{SS}} \times SS_{\text{eff.}}}{1 \times 10^6} \quad (7)$$

where

C_{total} : estimated total concentration in effluent, milligrams per liter of water

$C_{\text{diss.}}$: dissolved concentration as determined by modified elutriate tests, milligrams per liter of water

* D. K. Koussis, M. A. Saenz, and E. L. Thackston. 1982. "Evaluation of Hydraulic Models for Disposal Material Containment Areas," report prepared for the US Army Engineer Waterways Experiment Station, CE, 10-10-82, 10-10-82.

- F_{SS} = fraction of contaminant in the total suspended solids as calculated from modified elutriate results, milligrams per kilogram of suspended solids
- $SS_{eff.}$ = suspended solids concentration of effluent as estimated from evaluation of sedimentation performance, milligrams per liter of water
- 1×10^6 = conversion of milligrams per milligram to milligrams per kilogram

The acceptability of the proposed confined disposal operation can then be evaluated by comparing the predicted total contaminant concentrations with applicable water quality standards, considering an appropriate mixing zone. (Environmental Effects Laboratory 1976, EPA/CE 1977).

References

- Environmental Effects Laboratory. 1976. "Ecological Evaluation of Proposed Discharge of Dredged Material into Navigable Waters," Miscellaneous Paper D-76-17, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Environmental Protection Agency/Corps of Engineers. 1977. "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters, Implementation Manual for Section 103 of Public Law 92-532 (Marine Protection, Research, and Sanctuaries Act of 1972)," US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Environmental Protection Agency. 1980. "Guidelines for Specification of Disposal Sites for Dredged or Fill Material," Federal Register, Vol 45, No. 249, 24 December 1980, pp 85336-85358.
- Montgomery, R. L. 1978. "Methodology for Design of Fine-Grained Dredged Material Containment Areas for Solids Retention," Technical Report D-78-56, US Army Engineer Waterways Experiment station, Vicksburg, Miss.
- Palermo, M. R., Montgomery, R. L., and Poindexter, M. 1978. "Guidelines for Designing, Operating, and Managing Dredged Material Containment Areas," Technical Report DS-78-10, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Schroeder, P. R., et al. In preparation. "Hydraulic Efficiency of Confined Dredged Material Disposal Areas," Technical Report, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.



Environmental Effects of Dredging Technical Notes



INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--APPLICATION

PURPOSE: The following series of technical notes describe the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during disposal operations.*

EEDP-04-1	General
EEDP-04-2	Test Procedures
EEDP-04-3	Data Analysis
EEDP-04-4	Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operation (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluation of predictions and field measurement of effluent water quality.

BACKGROUND: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas during disposal operations (effluent) is a major environmental concern associated with such disposal.

Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (called supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant content is particle

* The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal sites.

associated. The modified elutriate test was developed for use in predicting both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980). Proposed testing requirements define dredged material according to four categories. Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of the short-term water column impacts of disposal area effluents. Predicted contaminant levels based on results of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

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Example 1: Evaluation of Effluent Water Quality for an Existing Disposal Area

Project information

Dredged material from a maintenance project will be placed in an existing disposal site. The site will be ponded over an area of approximately 35 acres. The design indicated that the surface area was adequate for effective sedimentation if a minimum ponding depth D_{pw} of 2 ft was maintained. The dredging equipment and anticipated pumping conditions will result in a flowrate of approximately 30 cfs. A field mean retention time of 20 hr was determined from a dye tracer test run during earlier disposal operations at this site under similar operational conditions. Previous sampling of inflow from the dredged pipe under similar conditions indicated an influent solids concentrations of approximately 150 g/l.

The quality of effluent must be predicted and compared to applicable water quality standards so that the acceptability of the proposed discharge can be evaluated. A mixing evaluation was conducted, and a dilution factor of 38 was determined for the allowable mixing zone. The water quality standard for copper at the perimeter of the mixing zone was c_r at 0.004 mg/l (whole water). The concentration of copper in the effluent at the point of discharge must, therefore, be less than 0.15 mg/l.

Modified elutriate test

Modified elutriate tests were conducted on samples of sediment and

water from three stations at the proposed dredging site. Modified elutriate tests were run at the anticipated influent solids concentration C_{slurry} of 150 g/l. Sediment samples from each sampling station were homogenized.

For one of the homogenized samples, a sediment solids concentration C_{sediment} of 450 g/l was determined by oven drying a sample of known volume. The volumes of sediment and water to be mixed to obtain 3-3/4 l of slurry with 150 g of solids per liter was determined as follows:

$$V_{\text{sediment}} = 3.75 \frac{C_{\text{slurry}}}{C_{\text{sediment}}} = 3.75 \frac{150}{450} = 1.25 \quad (1)$$

$$V_{\text{water}} = 3.75 - V_{\text{sediment}} = 3.75 - 1.25 = 2.50 \quad (2)$$

The modified elutriate tests were completed as described in Technical Note EEDP-04-2. A settling time of 20 hr was used since that was the estimated field retention for this case. Samples were extracted for the replicate tests and analyzed for total suspended solids and both dissolved and total concentration of contaminants of concern.

The total suspended solids concentration SS in one of the extracted samples was 40 mg/l. The dissolved concentration C_{diss} of copper in this sample was 0.06 mg/l, while the total concentration C_{total} of copper was 0.08 mg/l. The fraction of copper in the total suspended solids F_{SS} for this sample was determined as follows:

$$\begin{aligned} F_{\text{SS}} &= 1 \times 10^6 \left(\frac{C_{\text{total}} - C_{\text{diss}}}{\text{SS}} \right) \\ &= 1 \times 10^6 \left(\frac{0.08 - 0.06}{40} \right) \text{ or } 500 \text{ mg/kg SS} \end{aligned} \quad (3)$$

These calculations were repeated for other replicate tests, and the average dissolved and particulate copper concentrations were found to be 0.06 mg/l and 510 mg/kg SS, respectively.

Column settling test

Samples from all stations were homogenized into a composite for column settling tests. The test used for prediction of effluent suspended solids was run at a slurry concentration of 150 g/l, which was equal to the anticipated influent slurry concentration.

The interface was formed early in the test. Samples were extracted from

all ports above the interface at 3, 7, 14, 24, and 48 hr. The recorded observation and the subsequent computations are shown in Figure 1.

Since an interface formed in the test, the slurry mass was undergoing zone settling. Therefore, the initial supernatant solids concentration SS_0 was assumed equal to the highest concentration of the first port samples taken, 169 mg/l. In computing ϕ and constructing the concentration profile diagram (Figure 2), 169 mg/l was used as $\phi = 100$ percent.

The concentration profile diagram (Figure 2) was used for graphical determination of R , the percentage of solids removed, for the various time intervals at $z = 1, 2$, and 3 ft, which was the range of anticipated depths of withdrawal influence at the weir. This was done by using a planimeter to measure the area to the right of each concentration profile (defined by circled numbers in the figure) and computing its ratio to the total area above 1, 2, and 3 ft.

An example calculation of removal percentage for the concentration profile at $T = 14$ hr and a depth of influence of 2 ft is as follows:

$$R_{14} = \frac{\text{Area Right of Profile}}{\text{Total Area}} 100 = \frac{\text{Area 1-2-3-0}}{\text{Area 1-2-4-0}} 100 \text{ or } 78 \text{ percent} \quad (4)$$

The percentage of solids remaining at $T = 14$ hr was found as follows:

$$P_{14} = 100 - R_{14} = 100 - 78 \text{ or } 22 \text{ percent} \quad (5)$$

The value for the suspended solids remaining at $T = 14$ hr was determined as follows:

$$SS_{14} = \frac{P_{14}}{100} \times SS_0 = 0.22 \times 169 \text{ or } 37 \text{ mg/l} \quad (6)$$

Values at other times were determined in a similar manner. The data for the 2-ft depth of influence were compiled as shown in the following tabulation.

Sample Extraction Time t , hr	Removal Percentage R_t	Remaining Percentage P_t	Suspended Solids SS , mg/l
3	14	86	145
7	47	53	90
14	78	22	37
24	90	10	17
48	94	6	10

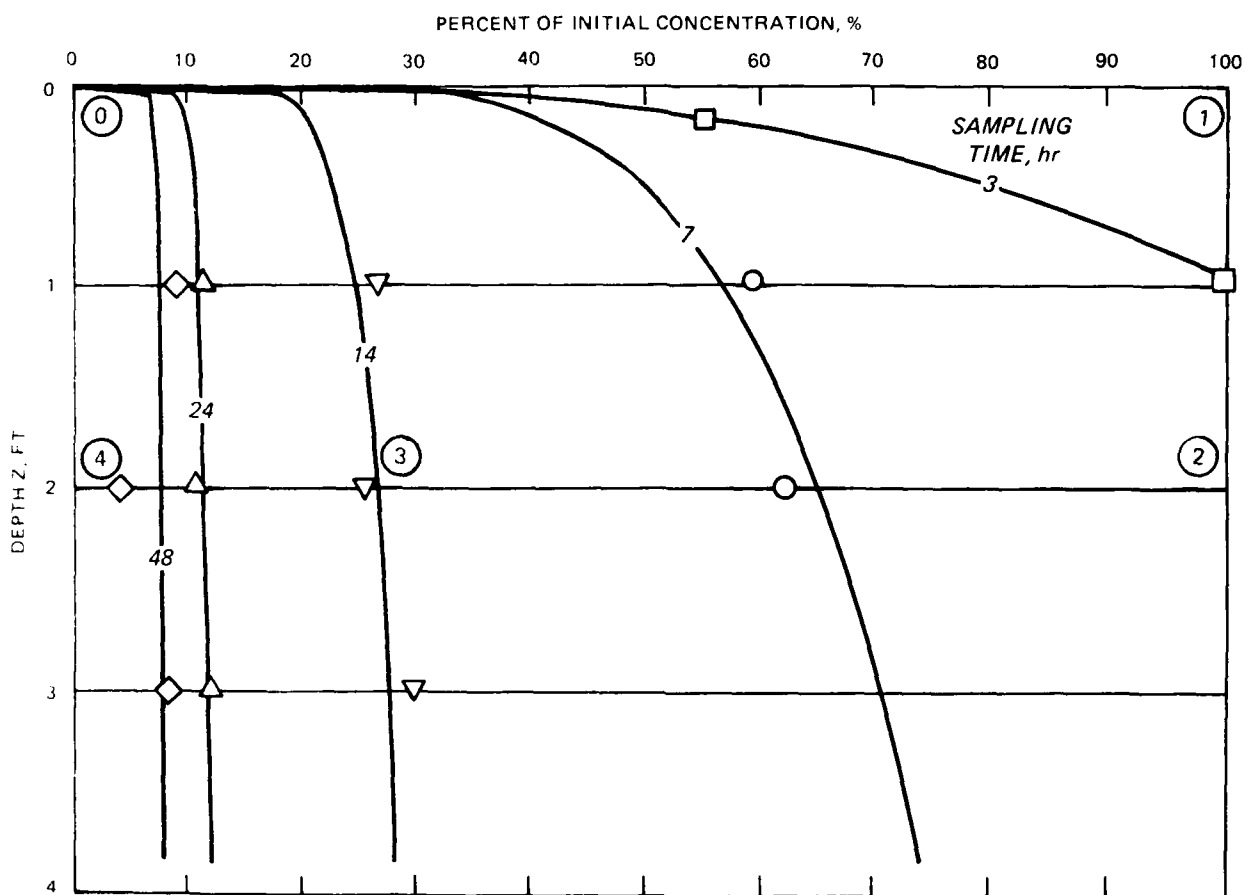


Figure 2. Concentration profile diagram

Similar calculations for other depths of influence were made. Curves were fitted to the total suspended solids versus retention time for depths of influence of 1, 2, and 3 ft, as shown in Figure 3.

Prediction of effluent suspended solids concentration

A value for effluent suspended solids can be determined for quiescent settling conditions using the column test relationships. In this case, the field mean retention time of 20 hr corresponds to a suspended solids concentration SS_{col} of 24 mg/l, as shown in Figure 3. This value should be adjusted for anticipated resuspension using the resuspension factors as given in Technical Note EEDP-04-3:

Anticipated Ponded Area acres	Resuspension Factor- Average Ponded Depth	
	Less than 2 ft	2 ft or Greater
Less than 100	2.0	1.5
Greater than 100	2.5	2.0

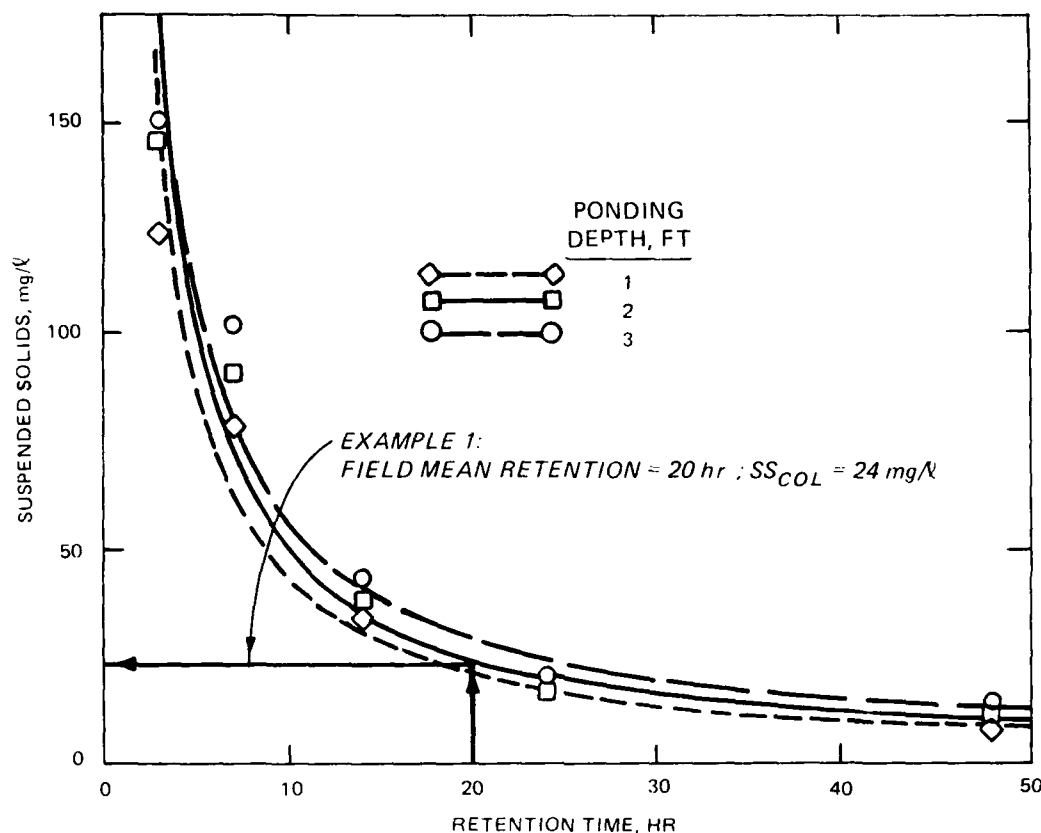


Figure 3. Suspended solids concentration estimated from column settling test

In this case, for a surface area less than 100 acres and average ponding depth of 2 ft, the resuspension factor RF is 1.5. The predicted total suspended solids concentration SS_{eff} in the effluent is calculated as follows:

$$SS_{eff} = SS_{col} \times RF = 24 \text{ mg/l} \times 1.5 \text{ or } 36 \text{ mg/l} \quad (7)$$

Prediction of contaminant concentrations

The modified elutriate test results indicated that the concentration of dissolved copper C_{diss} would be 0.06 mg/l and that the fraction of copper in the total suspended solids F_{SS} would be 510 mg/kg. The predicted total suspended solids concentration in the effluent SS_{eff} is 36 mg/l. The predicted concentration of total copper in the effluent C_{total} is calculated as follows:

$$C_{total} = C_{diss} + \frac{F_{SS} \times SS_{eff}}{1 \times 10^6} = 0.06 + \frac{510 \times 36}{1 \times 10^6} = 0.078 \text{ or } 0.08 \text{ mg/l} \quad (8)$$

The estimated concentrations of other contaminants in the disposal area

effluent can be determined in a similar manner. The acceptability of the proposed discharge can be evaluated by comparing the estimated effluent concentrations with applicable water-quality standards, considering an appropriate mixing zone. For total copper, the predicted concentration of 0.08 mg/l at the point of discharge is less than the maximum of 0.15 mg/l specified in the water-quality standards. The discharge would therefore be acceptable.

Example 2: Determination of Disposal Area Requirements to Meet a Given Effluent Quality Standard

Project information

A disposal area is planned for contaminated sediment from a small maintenance dredging project. Dredging plant traditionally used in the project area is capable of flowrates up to 15 cfs. Available real estate in the project vicinity is scarce with the maximum available area limited to 60 acres. The minimum disposal area requirements to meet applicable water-quality standards must be determined.

The design using procedures described by Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978) indicated that a minimum ponded surface of 20 acres was required for effective sedimentation, assuming a flow rate of 15 cfs and a minimum ponding depth of 2 ft. A mixing evaluation was conducted and a dilution factor of 60 was determined for the allowable mixing zone. The water-quality standard for PCB at the perimeter of the mixing zone was set at 0.00003 mg/l. The concentrations of PCB in the effluent (at the point of discharge) must therefore be less than 0.0018 mg/l to meet the standards, considering an appropriate mixing zone.

Modified elutriate test

Modified elutriate tests were conducted and calculations made as described for Example 1. For this example, the mean field retention time for the proposed disposal area was not known, so the maximum laboratory retention of 24 hr was used for the tests. Since the inflow concentration was not known, the tests were run at a slurry concentration of 150 g/l. Results for replicate tests for this example were 0.001 mg/l for the concentration of dissolved PCB C_{diss} and 44 mg/kg for the fraction of PCB in the total suspended solids F_{SS} .

Column settling test

Column settling tests were run at a slurry concentration of 150 g/l ,

and the resulting concentration profile was developed as in Example 1 (Figure 2). For simplicity, the results of the column settling tests used in Example 1 will also be used for this example.

Determination of required effluent suspended solids concentration

Since this requires determination of disposal site characteristics to meet a given water-quality standard, the calculations proceeded in a manner similar to Example 1, but in a reverse sequence. The concentration of effluent suspended solids SS_{eff} required to meet water-quality standards must first be determined. For total PCB C_{total} , the standard at the point of discharge is 0.0018 mg/l. The suspended solids concentration required to meet this standard is calculated as follows:

$$C_{total} = C_{diss} + \frac{F_{SS} \times SS_{eff}}{1 \times 10^6} \quad (9)$$

or transposed,

$$\begin{aligned} SS_{eff} &= \frac{1 \times 10^6}{F_{SS}} (C_{total} - C_{diss}) \\ &= \frac{1 \times 10^6}{44.0} (0.0018 - 0.001) \text{ or } 18 \text{ mg/l} \end{aligned}$$

Based on this calculation, the effluent suspended solids concentration cannot exceed 18 mg/l without exceeding the standard for PCB. Similar determinations should be made for other contaminants being considered in order to define the limiting value for the required effluent suspended solids concentration. For this example, 18 mg/l was used as the limiting value.

Since the final site configuration is not known, a conservative resuspension factor RF should be selected from the tabulation given in Example 1. The minimum ponding depth of 2 ft required by the site design is used. A resuspension factor of 1.5 was selected corresponding to an area less than 100 acres and ponding depth of 2 ft.

The value of 18 mg/l suspended solids (including resuspended particles) must be met at the point of discharge. The corresponding value for total suspended solids concentration under quiescent settling condition is determined by transposing Equation 7 ($SS_{eff} = SS_{col} \times RF$) as follows:

$$SS_{col} = \frac{SS_{eff}}{RF} = \frac{18 \text{ mg/l}}{1.5} \text{ or } 12 \text{ mg/l}$$

The required configuration of the disposal area must correspond to a retention time that will allow the necessary sedimentation. The required retention time to achieve 12 mg/l under quiescent settling conditions can be determined from the laboratory column relationship for suspended solids versus retention time.

Using the concentration profile data and the assumed depth of ponding at the weir of 2 ft, the relationship for suspended solids versus field mean retention was developed as shown in Figure 4. Using Figure 4, 12 mg/l corresponds to a field mean retention time T_d of 36 hr. To determine the required disposal site geometry, the theoretical retention time T should be used. Since no other data were available, the hydraulic efficiency factor HEF was assumed as 2.25. The theoretical retention time T was calculated as follows:

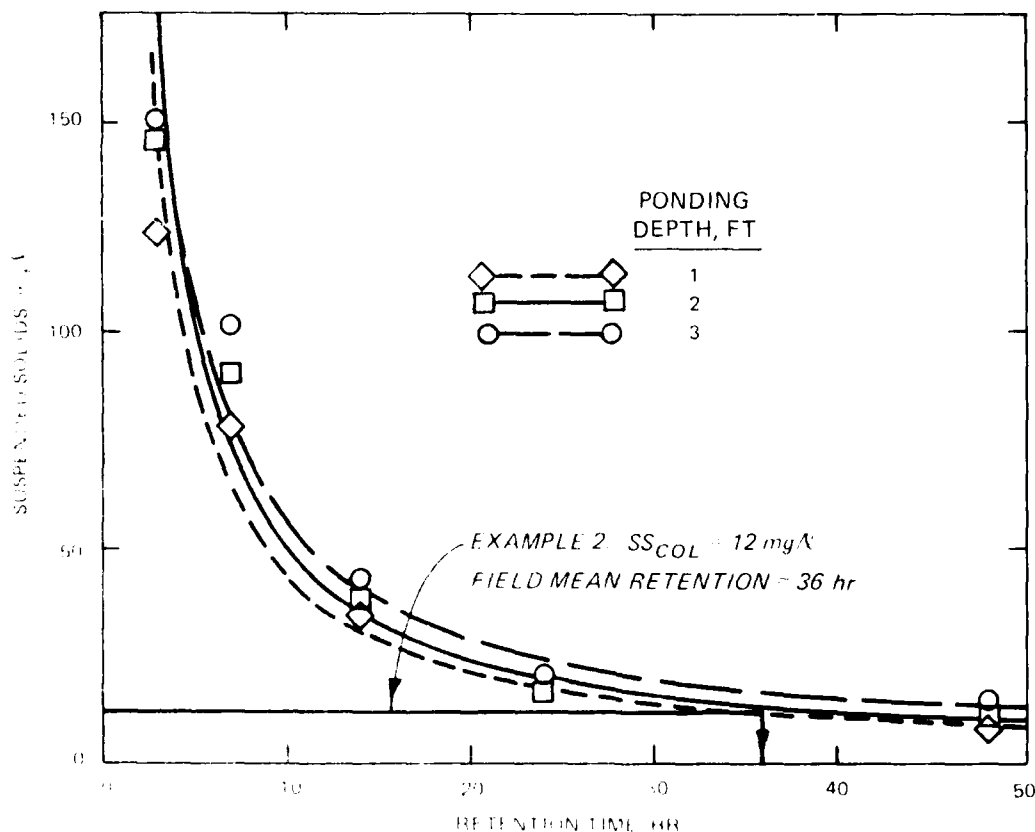


Figure 4. Field mean retention time estimated from column settling test

$$t_d = \frac{T}{(HEF)} \quad (10)$$

transposed to

$$T = T_d (HEF) = 36 (2.25) \text{ or } 81 \text{ hr}$$

Determination of disposal area configuration

The disposal area configuration can now be determined using data on anticipated flowrate and the required retention time. Since the dredging equipment available in the project area is capable of flowrates up to 15 cfs, the high value should be assumed.

The pond volume required is calculated as follows:

$$T = \frac{V_p}{Q_i} \quad (12.1) \quad (11)$$

transposed to

$$V_p = \frac{T Q_i}{12.1} = \frac{81 \text{ hr} \times 15 \text{ cfs}}{12.1} \text{ or } 100 \text{ acre-ft}$$

A ponding depth of 2 ft is the minimum required. This same depth should be maintained over the entire ponded surface area and at the weir. The disposal site should, therefore, encompass approximately 50 acres of ponded surface area if the dredge selected for the project has an effective flowrate not greater than 15 cfs. The surface area of 50 acres required to meet the water-quality standard controls over the design surface area of 20 acres required for effective sedimentation.

References

Environmental Effects Laboratory. 1976. "Ecological Evaluation of Proposed Discharges of Dredged Material into Navigable Water," Miscellaneous Paper 76-17, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Environmental Protection Agency. 1980. "Guidelines for Specification of Disposal Sites for Dredged or Fill Material," Federal Register, Vol. 45, No. 249, 85336-85358.

Environmental Protection Agency/Corps of Engineers. 1977. "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Water, Implementation Manual for Section 103 of Public Law 95-532 (Marine Protection, Research, and Sanctuaries Act of 1972), US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Montgomery, R. L. 1978. "Methodology for Design of Fine-Grained Dredged Material Containment Areas for Solids Retention," Technical Report D-78-56, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Merino, M. R., Montgomery, R. L., and Poindexter, M. 1978. "Guidelines for Designing, Operating, and Managing Dredged Material Containment Areas," Technical Report DS-78-10, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

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